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Interrelations Among Child Mortality, Breastfeeding, and Fertility in Egypt, 1975-80

John Marcotte
and
John B. Casterline

Weaning children in infancy increases the risk of death for Egyptian children under five. Early weaning should be discouraged. Parents should be encouraged to be more careful about childcare and children's diet and hygiene after weaning.

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This paper — a product of the Population, Health, and Nutrition Division, Population and Human Resources Department — is part of a larger effort in PRE to examine family consequences of high fertility. Copies are available free from the World Bank, 1818 H Street NW, Washington DC 20433. Please contact Susan Cochrane, room S6-139, extension 33222 (52 pages, including tables).

Using Egyptian data from 1975-80, Marcotte and Casterline found that weaning children in infancy increases the risk of death for children under five. Early weaning is responsible for up to 29 percent of Egyptian children's deaths.

Children whose mothers become pregnant again are more likely to die if the pregnancy begins while the child is still an infant. Ending breastfeeding is responsible for up to 41 percent of pregnancies — 52 percent among women who do not use contraceptives.

Breastfeeding lasts an average 17 to 18 months in Egypt, so policy should probably not encourage all women to breastfeed longer, but women who breastfeed for only short periods should probably be encouraged to breastfeed longer. And parents should be encouraged to be more careful about childcare and children's diet and hygiene after weaning.

Replacement behavior in response to children's death accounts for up to 18 percent of pregnancies. It is not actual mortality but perceptions of a child's chances for survival that drive fertility. As infant deaths become less common, the proportion of replacement pregnancies should decline.

An important feature of this analysis was that fertility (represented by pregnancy) was examined simultaneously with child survival and breastfeeding, as three components of a system. The analysis involved regression models for the hazard, or risk, of three events occurring after a live birth: another pregnancy, weaning, or the death of the child.

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I. INTRODUCTION

This report examines the relationship between reproductive behavior and child survival in Egypt. The relationship is of fundamental importance to an understanding of demographic dynamics in Egypt and for the formulation of population policies.

Various facets of the fertility - mortality relationship have been central concerns of demographic theory and research for many decades. Classical demographic transition theory, as formulated in the 1930s - 1950s, posits a lagged response of fertility to mortality: mortality declines, themselves a consequence of exogenous improvements in standards of living and public health services, prompt corresponding declines in fertility, in order to prevent sustained rapid population growth and the stresses it causes to families and larger social groups. A review of the empirical evidence in the mid-1970s concluded that neither aggregate-level nor micro-level responses of fertility to infant and child mortality of the magnitude implied by classical demographic transition theory could be detected in historical European and contemporary Third World data (Preston, 1978). A more recent detailed micro-level investigation with World Fertility Survey (WFS) data from 25 developing countries (not including Egypt) suggests a somewhat stronger fertility response; nevertheless, on average the estimated response is one-half a birth for each child death, i.e. far from full fertility compensation for child deaths (Cochrane and Zachariah, 1984). The fertility response can consist of voluntary and involuntary components; the mechanisms that may operate at the micro-level will be described in more detail in section II of this report.

The impact of fertility on child survival has been a topic of a substantial body of empirical research during the past decade. Micro-level studies, many of them utilizing WFS data, have examined the impact on child survival of maternal age, maternal parity, and the timing of preceding and subsequent pregnancies (eg. Winikoff, 1983; Cleland and Sather, 1984; Hobcraft, et al., 1985; Palloni and Millman, 1986). Each of these three aspects of reproduction - maternal age, parity, and interval lengths - have been demonstrated to influence the likelihood of a birth surviving infancy and early childhood, with the impact of preceding and subsequent pregnancy (or birth) intervals being particularly large.

Previous analyses of Egyptian data have considered the relationship between reproductive behavior and child survival. A set of analyses of the Egyptian Fertility Survey (1980) have examined the micro-level effects. With respect to the impact of child survival on fertility, Callum, Farid, and Moussa (1988) show that birth intervals following infant deaths are substantially shorter than intervals following births that survive infancy. In addition to involuntary biological effects, behavioral (eg. contraceptive use patterns) and attitudinal (eg. desire for additional births) responses to infant and child mortality are both evident. With respect to the impact of fertility on child survival, maternal age, parity, and the length of the preceding birth interval have statistically significant and large net effects on infant mortality: births to women under age 20 or over age 39, births of parity seven and greater, and births following a preceding birth by less than 24 months are all distinctly disadvantaged (Eid and Casterline, 1988). Parity and length of the preceding birth interval, but not maternal age, also influence survival between age 1 and 5. A more detailed study of the birth spacing effect demonstrates a significant net effect of the preceding <u>and</u> the succeeding interval (Callum and Cleland, 1988).

In this report, we consider again the micro-level relationship between reproductive behavior and child survival in Egypt, drawing once again on the rich set of information provided by the Egyptian Fertility Survey of 1980. The analysis we carry out is distinguished from previous analyses in the following respects.

First, we introduce breastfeeding behavior (specifically, the act of weaning) as a major component of reproductive behavior that influences both the survival of the child and the timing of the next conception. Especially in populations in which there is little regulation of marital fertility through contraception, breastfe.ding is a key variable for understanding the relationship between fertility and mortality. Palloni and Millman (1986) and Retherford et al. (1989) have investigated the contribution of breastfeeding to the estimated effect of birth spacing on child survival. In the former study, based on data from Latin America (where weaning occurs relatively early and contraceptive prevalence is relatively high), the contribution appears to be minor; in the latter study, based on data from Nepal (where the average breastfeeding duration is relatively long and contraception is virtually absent), breastfeeding appears to be the chief factor mediating the effect of birth spacing on child survival.

Second, we model fertility, child survival, and breastfeeding as a micro-level system. The estimation approach we adopt permits a full set of effects to operate simultaneously. In this respect, the estimation approach a ords with our conceptualization of the micro-level system, which acknowledges a host of reciprocal effects linking fertility, child survival, and breastfeeding (Cochrane and Zachariah, 1984).

The remainder of the report is organized as follows. In section II, we review the hypothesized mechanisms linking fertility, child survival, and breastfeeding at the micro-level. Section III describes the estimation approach and the data employed in the analysis. Results are presented in section IV. Four appendices attached to the main body of the report provide more detail about the statistical models, the data, and the results.

II. MECHANISMS LINKING FERTILITY, CHILD SURVIVAL, AND BREASTFEEDING

A. The three events

As indicated above, there are both macro- and micro-level facets to the relationship between reproductive behavior and mortality. At the micro-level, one can choose between women and births (or pregnancies) as units of analysis. It is natural to choose births as the unit of analysis, as many of the dynamics of interest refer to births (eg. survival, breastfeeding) or to intervals between births (time to next conception, contraceptive use). On theoretical grounds, however, it is essential to retain some connection to the woman (or couple) as the fundamental decision-maker. For example, the deleterious impact on child survival of intense fertility (large numbers of pregnancies, closely-spaced pregnancies, or births at very young ages) may persist over many births; and deliberate responses to child loss may persist over long stretches of a reproductive career. In this analysis, births are chosen as the unit of analysis. Features of the past reproductive career of the woman (parity, length of the previous interval, age at the birth) are incorporated as covariates, but their estimated effects are given minimal attention here, as these have been analyzed in detail elsewhere (see discussion in section I). Instead, the inter-relations between fertility, child survival, and breastfeeding are examined on a birth-by-birth (or interval-by-interval) basis. To the extent that relationships among these three variables exist that are only expressed over the long-term reproductive career, this analysis offers an incomplete portrait of the pertinent relationships.

Consider the fertility-mortality-breastfeeding system as consisting of the relationships among three events that may follow a live birth: the termination of breastfeeding (i.e., the weaning of the child); the death of the child; the birth of the next child (Marcotte, 1988). Clearly the latter two events need not occur for every birth; indeed, death of the child is a relatively rare event in most human populations. Breastfeeding eventually ends for all children; but in those cases where the child is breastfed until death, death effectively censors breastfeeding and the child is never weaned. Any one of the three events may not have occurred as of the time of data collection, i.e. they may be censored by the interview. A final point is that, where the data allow, it is preferable to use the onset of the next pregnancy (live or non-live outcome) rather than the next live birth as the fertility event, as most of the hypothesized effects concern pregnancy. (That is, weaning and mortality responses to the next pregnancy can occur during the pregnancy, prior to the next live birth).

Hence, we have three events to model jointly: weaning, death, next pregnancy. These three events are the basic drivers of demographic change. Particularly in societies where deliberate contraceptive behavior is rare - a situation typifying much of Africa (North and sub-Saharan) - to a considerable extent population dynamics (size, rate of growth, age structure) can be accounted for by simple aggregation of the risk of these three events occurring (singly and jointly). The contraceptive prevalence rate in Egypt at the time of the Egyptian Fertility Survey (the data used in this study) was roughly sixteen per cent, rather high by African standards but still indicative of the large-scale absence of modern contraceptive efforts.

As noted above, following a birth all three events can occur, or two of them can occur, or one, or none (since a death can preclude weaning). Due to censoring by the interview, one or more of the events that will eventually occur may not be observed. The events can occur in any order, with the exception of weaning following death. We view the child as progressing through a series of states following its birth. For example, a few months after giving birth a woman may stop breastfeeding (i.e., the child enters the state of weaned); a few months later, she may become pregnant (i.e., the child enters the state of next pregnancy); and perhaps a few months later, the child may die (ie, the child enters the state of death). In this example, weaning is followed by next pregnancy which is followed by death; other sequences can easily be imagined.

In this analysis, we examine how the occurrence of one of the three events modifies the likelihood of the occurrence of each of the other two events. The occurrence of one event is hypothesized to shift (upward or downward) the hazard for each of the other two events. The method of estimation makes use of the precise dating (on a monthly basis) of each event, but the results are driven mainly by the ordering of the events. The estimation is robust to some imprecision in the dating of events so long as the ordering is accurate. In particular, accurate ordering of events is essential to the estimation of reciprocal effects, such as weaning on fertility and fertility on weaning. Disentanglement of the reciprocal effects is accomplished by assuming that chronological order implies causal order.

The approach might be criticized for not taking into account the timing of the events (i.e., months since the birth): it is plausible, for example, that early weaning (prior to age twelve months, for example) has different implications for the risk of dying than late weaning. To allow for timing effects, we explicitly estimate separate effects of early and late occurrence of events. (Overall effects are also presented.)

Marcotte (1988) introduces the conceptual model and the estimation approach. The estimation approach is described in section III, with greater detail provided in Appendices A and B.

B. Mechanisms

We consider five effects: weaning on child death and on next pregnancy; next pregnancy on child death and on weaning; and child death on next pregnancy. (Child death precludes weaning; an effect of child death on weaning is therefore ruled out.) Note that these five effects imply a number of indirect effects: weaning can affect child death through the next pregnancy; weaning can affect the next pregnancy through child death; and the next pregnancy can influence child death through weaning. An innovation in the analysis presented below is that indirect effects are explicitly estimated and, moreover, total effects are decomposed as sums of direct and indirect effects, thereby providing a more complete description of the processes at work. (The decomposition technique is specified in section III.)

Let us briefly review the mechanisms underlying each of the five effects. Effects that operate directly and indirectly (through one of the other events) are both described.

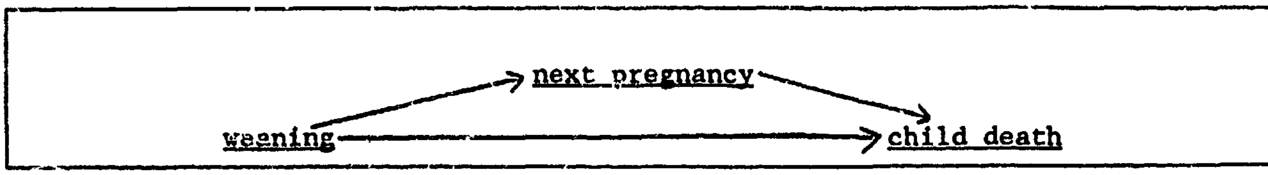

figure 1

(1) Weaning on child death [figure 1].

Direct: Cessation of breastfeeding, if not fully compensated by food substitutes, can result in poorer nutrition (caloric intake, nutritional balance). In addition, food substitutes lack the antibodies provided by breastmilk, and unhygienic preparation can lead to infection.

Indirect: Weaning can exercise an indirect influence on child death by raising the risk of the occurrence of the next pregnancy (see (2)), which is posited to have an effect on the risk of child death (see (3)) even when breastfeeding duration is controlled.

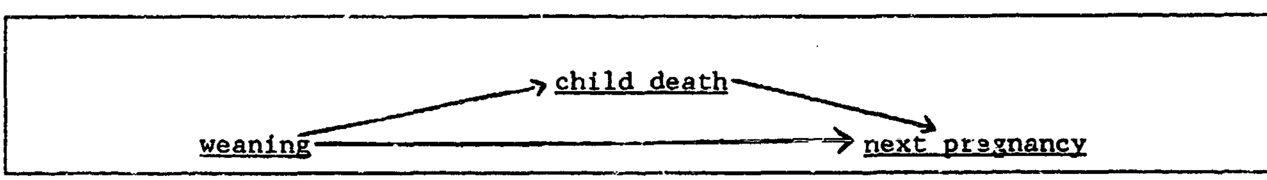

figure 2

(2) Weaning on next pregnancy [figure 2].

Direct: The dominant mechanism underlying this effect is the suppressing effect of lactation on ovulation (through the maintenance of high levels of the hormone prolactin). Additional mechanisms: customs about sexual behavior during lactation can result in coital frequency increasing sharply after weaning, increasing the risk of a next pregnancy; customs about contraceptive practice, in contrast, can result in more intense contraception after weaning, reducing the risk of a next pregnancy.

Indirect: Weaning can influence the risk of the next pregnancy indirectly by affecting the risk of death (see (1)), which itself affects the risk of a next pregnancy (see (5)) The death of a child in less developed countries often prompts replacement fertility behaviors.

$$\begin{tikzcd} & \text{weaning} \arrow[dr] & \\ \text{next pregnancy} \arrow[ur] \arrow[rr] & & \text{child death} \end{tikzcd}$$

figure 3

(3) Next pregnancy on child death [figure 3].

Direct: A pregnancy competes with the child for maternal resources (nutrition, care). This competition begins prior to parturition and becomes more directly evident thereafter.

Indirect: The next pregnancy can exercise an indirect effect on child survival through an effect on weaning (see (4)) and weaning's subsequent effect on child death (see (1)).

$$\text{next pregnancy} \longrightarrow \text{weaning}$$

figure 4

(4) Next pregnancy on weaning [figure 4].

Direct: While lactation suppresses ovulation (the fundamental mechanism underlying effect (2)), once conception occurs prolactin levels drop and lactation must diminish. Physical exhaustion induced by the pregnancy may also lead to substitution of other foods for breastmilk, since other foods can be prepared and given to the child by individuals other than the mother.

$$\underline{\text{child death}} \longrightarrow \underline{\text{next pregnancy}}$$

figure 5

<u>(5) Child death on next pregnancy [figure 5].</u>

Direct: The direct effects of child death on the risk of a next pregnancy are due to behavioral responses to the death, such as changes in contraceptive practice and in coital frequency. These changes may be motivated by a conscious desire to replace the deceased child or to accelerate the arrival of the next child.

Indirect: The effect of death on the risk of the next pregnancy is typically assumed to operate primarily through the cessation of breastfeeding. However, in behavioral terms, child death does not cause weaning; rather, child death censors breastfeeding. Thus, we do not allow for an indirect effect of child death on next pregnancy through weaning. But since we estimate all five effects as components of one overall system, the effects of child death on next pregnancy are estimated allowing for weaning effects on next pregnancy.

Our discussion of the mechanisms underlying the five effects has implicitly assumed a natural fertility, as opposed to a controlled fertility, population. The distinction is most salient with reference to effects on the next pregnancy: weaning on next pregnancy (see (2)), and child death on next pregnancy (see (5)). These two effects are the result, in part, of changes in coital frequency and in contraceptive behavior. These two mechanisms operate in both non-contracepting and contracepting populations but to a lesser extent in the latter. Nevertheless, almost certainly the effect of weaning on the risk of a next pregnancy is much more powerful where fertility is not regulated by contraception; indeed, in such settings it may be the chief determinant of the level of marital fertility (Bongaarts, 1983). To permit empirical examination of how fertility control conditions the strengths of relationships, we estimate effects on the next pregnancy (of weaning and of child death) separately for birth intervals (closed and open) in which the woman reported not using and using contraception. For completeness, we estimate all five effects for both types of intervals. On theoretical grounds, all five effects can occur under conditions of unregulated or regulated fertility.

III. DATA AND ESTIMATION

A. The data

The data are from the Egyptian Fertility Survey, conducted in 1980 as part of the World Fertility Survey programme and in collaboration with the World Bank. The executing agency for the survey was the Central Agency for Public Mobilisation and Statistics (CAPMAS). The principal findings of the survey are presented in the four-volume survey report (CAPMAS, 1983) and in a further volume of in-depth analyses (Hallouda, Farid, and Cochrane, 1988). The EFS documents that Egypt is characterized by relatively high infant and child mortality (the infant mortality rate is roughly 130 for the five years preceding the survey), high fertility (a TFR of 5.27 for the five years preceding the survey), and long durations of breastfeeding (an average age at weaning of 17 months). About one-quarter (24%) of currently-married women of reproductive age reported using some method of contraception in the five years prior to the survey, with the contraceptive pill the most popular method. The percentage of contraceptive users in our sample (24%) is different than in the total sample (16%) because our sample contains births in the five years prior to survey while the percentage for the total sample is based on current status.

A complete pregnancy history (live and non-live births) was obtained in the EFS. For each live birth, survival status at the survey was ascertained, and the age at death (in months) of those children who died. Duration of breastfeeding of the most recent two live births was also obtained. Thus, with the EFS data it is possible to determine, for recent births, the ages (in months) at death, weaning, and next pregnancy. (For all children, age at next pregnancy is calculated by subtracting nine months from the age at the birth of the next child; if the next pregnancy terminates in a non-live-birth outcome, the reported gestational length is used in the calculation. For those children who die before their mothers become pregnant again, age at next pregnancy is the age that the child would have attained if he had survived.)

Because the EFS histories are collected retrospectively and only from women aged 15-49 at the time of the survey, the sample for this analysis is restricted to last and next-to-last births occurring within five years (60 months) of the survey. The five-year constraint is imposed for three reasons. First, it mitigates selection problems that result from using retrospective reports from a sample of women with an upper age restriction (49 in this instance). As the time period from which births are drawn is extended backwards, the data represent a smaller and smaller fraction of women in the childbearing ages and thus the sample becomes selective of certain maternal characteristics. In the five years preceding the survey, only children born to women aged 50-54 at the time of the survey are omitted, a negligible loss. The second reason for the time period restriction is to maximize reliability. We assume that information about events closer to the survey is of higher quality (more complete coverage, more accurate dating). Thirdly, the EFS contains breastfeeding information for the last two children only, hence the restriction of the sample to last and next-to-last births. The further back that the time period of observation is extended, the more selective last and next-to-last births become of all births in the period. Over three-fourths (78%) of the births occurring in the five years immediately prior to the survey are either last or next-to-last births. Clearly an observation period briefer than five years would further alleviate each of these three problems. But a shorter time period would lead to less precise estimates, due to a smaller number of observations; it would also result in a higher proportion of events censored by the survey..

Note that because of restriction of the sample to births in the sixty months preceding the survey, the longest possible interval between birth and onset of next pregnancy is sixty months. In Egypt, as in other moderate and high fertility settings, the majority of parity progressions will occur long before sixty months (Hobcraft and McDonald, 1984). Furthermore, the causal factors of principal concern in this analysis, namely death and weaning, should have little influence on the risk of pregnancy after sixty months.

We impose several additional restrictions on the data, to control potentially confounding factors. Non-Muslim women are excluded, in an effort to eliminate unmeasured heterogeneity in post-partum practices (abstinence, child feeding). This restriction eliminates less than ten per cent of births occurring during the reference period. Multiple births are excluded because information on the breastfeeding of such births is known to be unreliable in many fertility surveys. This restriction affects about two per cent of births Finally, we control sexual exposure by excluding births to women with marital disruption prior to any one of the three events and women who report that their husband was abroad at the time of interview. Unmarried women and women separated from their spouses have very low risk of becoming pregnant. Few children are lost because of these restrictions. The sample for analysis consists of 7375 children.

To mitigate spurious relationships among child death, weaning and next pregnancy, a standard set of variables are included in all estimations as controls. These variables are: parity, age of mother, length of preceding birth interval, sex of child, region (Lower and Upper), size of place of residence (Cairo and Alexandria, other urban places, rural), maternal and paternal literacy and schooling, and whether contraception is used in the interval following the birth. In selecting these variables, we draw on the extensive analysis of the EFS (analyses of fertility, child survival, and breastfeeding) that has already been completed (Hallouda, Farid, and Cochrane, 1988). (See Appendix C for definition of the control variables.)

B. Estimation

We use hazard model techniques to estimate effects. The hazard is the instantaneous rate of an event occurring at a particular time. Coefficients represent how much higher or lower, in relative terms, is the hazard for one group as compared with another group. Full information maximum likelihood is the method of estimation. We estimate all parameters in the three event system simultaneously. The likelihood is a combination of the survival distributions for the three events. To operationalize the model, we use two parametric survival distributions, the Weibull and log-logistic. Under the Weibull, the hazard of an event occurring must increase or decrease monotonically while under, the log-logistic the hazard increases to a maximum and then declines. The Weibull is well suited for mortality under age five where the hazard of death decreases with age, and for weaning where the hazard increases with age. The hazard of a next pregnancy occurring follows a roughly log-logistic pattern: the hazard is low in the months immediately following a birth, rises to a maximum in the period 10 to 36 months following a birth and then declines. The likelihood is a combination of pieces that represent progressions between events. While it is complex with a large number of terms, the likelihood is, nevertheless, well defined. Appendix A shows the probability distributions and the terms of the likelihood). With standard maximization techniques (the Levenberg-Marquardt method), we obtain parameter estimates.

The sequence of the occurrence of events is essential to the estimation of the system. Indeed, the accuracy of the sequence of events is more essential than the accuracy of the ages themselves: the estimation of progression effects relies on sequence. It is on the basis of sequence that reciprocal effects are estimated. For example, the model contains parameters that represent both the impact of weaning on the hazard of next pregnancy and the onset of the next pregnancy on the hazard of weaning. The measurement of ages in the EFS no doubt contains inaccuracies. The most glaring evidence of this is the high degree of heaping on certain ages (multiples of six months) evident in the information on age at death and age at weaning (Eid and Casterline, 1988; Akin, *et al.*, 1988). The shifting of reported ages from true values to certain convenient values can reduce the reliability of the ordering of the three ages of interest.

The reliance on the sequence of events has further implications. For state A to influence state B, state A must occur first. When two events occur at the same age, effects of one event on the other are not plausible, even though both events occur. This point is especially pertinent to estimation of the relationship between death and weaning. When death occurs prior to weaning, retrospective survey data may show that death and weaning occur in the same month. In reality, death has <u>censored</u> weaning, and the child remains unweaned even though the child is dead. It is important to recognize that death can censor weaning; failure to recognize this fact can lead to estimation of effects of breastfeeding on mortality that are seriously upwardly-biased. The problem is potentially acute in Egypt: because of the long durations of nursing, a large proportion of infant deaths are likely to occur prior to weaning (i.e., death curtails breastfeeding) The observed weaned children are, therefore, selected with respect to survival, so weaning will appear to reduce the risk of dying. To mitigate this selection problem, in this analysis the models for mortality contain a parameter for the equality of breastfeeding duration and age at death. In effect, those cases for which the two ages are equal have been separated out and do not contribute to the estimation of the reciprocal relationship between weaning and death. That is when these two ages are equal, it is assumed that the child is not weaned. All mortality probability functions include this parameter, which acts as a selection control only and does not have a causal interpretation.

As an alternative to the parametric model employed in this analysis, one might choose a semi-parametric specification. The Cox proportional hazards model is well known in demographic research. In the EFS data, survival times are heavily tied (partially due to heaping), however, which makes the semi-parametric model difficult to operationalize. Another limitation of the semi-parametric model is that shifts in the hazard that are attributable to the occurrences of the other events (i.e. time dependent covariates) are computationally difficult to estimate. Even with the parametric approach adopted here, estimation is computationally intensive. A final reason for preferring a parametric specification is that the decomposition of effects into direct and indirect effects is more easily defined and computationally more straightforward.

C. Analytic approach

Following the discussion in section II of this report, we present results for three samples of births: (1) all births; (2) births to mothers who do not practice contraception prior to the next birth; (3) and births to mothers who do practice contraception prior to the next birth. As argued in section II, we expect the strength of some of the effects to vary according to the presence or absence of fertility regulation. The measure of contraceptive practice is crude, however. The data only indicate the presence or absence of contraception in the interval; no information is provided on the timing of use. The crudeness of the measure is particularly a concern with respect to the "regulators", who probably differ substantially among themselves in their contraceptive practice. Undoubtedly, net effects of this variable reflect more than fertility regulation *per se*; the variable possibly selects on access to health care and on infant feeding practices (intensity of breastfeeding, supplemental feeding regime). Another selection problem is that women with longer birth intervals may become "regulators" simply because they have had more time to adopt the practice. Information on timing of contraceptive use would permit a more refined partitioning of the sample, but the EFS does not contain this information.

We convert model coefficients into <u>relative risk</u> and <u>attributable risk</u> estimates. The <u>relative risk</u> shows by how much the occurrence of one event multiplies the hazard of another event occurring. A relative risk of 1.00 indicates no effect. A relative risk greater than 1.00 indicates that the occurrence of one event elevates the hazard of another event; a relative risk less than 1.00 implies reduction in the hazard. While the relative risk is a standard measure of effect in hazard models, the attributable risk has greater policy value. The <u>attributable risk</u> represents the percentage of events for which a particular characteristic is responsible. Walter (1976) discusses the estimation and interpretation of the attributable risk. For example, an attributable risk of 35.0 indicates that a particular characteristic accounts for thirty-five per cent of events. If the attributable risk for weaning with respect to child death were 35.0, then up to thirty-five per cent of child deaths occur because of weaning. The attributable risk is influenced both by the relative risk and by the proportion of the population with a particular characteristic. Note that the attributable risk represents a maximum attribution. Note further that, depending on the events under consideration, it may not be feasible to reduce the risk by the amount indicated by the attributable risk; for example, it is not feasible to eliminate the weaning of children in Egypt. Use of attributable risks for policy purposes must be done with care. (See Appendix B for further details on relative and attributable risks.)

We decompose relative risks into direct and indirect components. The decomposition shows what per cent of the effect of a particular factor is mediated through an intervening variable. The decomposition further clarifies the mechanisms operating in the system. As noted in section II, many of the effects of interest are hypothesized to exercise both direct and indirect effects. For example, weaning influences mortality directly and indirectly (through modifying the risk of next pregnancy). To our knowledge, the direct and indirect effects linking child death, weaning, and next pregnancy have not been presented elsewhere. (See Appendix B for further details.)

IV. RESULTS

We have three events (death, next pregnancy, and weaning) and five effects (i.e. all possible effects except death on weaning, which we rule out definitionally) to consider. We organize the presentation of results in terms of outcomes, beginning with child death as an outcome, then considering next pregnancy, and finally weaning.

A. Mortality

A.1 Effects of weaning on child death [see figure 1]

Since the sample is restricted to children born within 60 months (five years) of the survey, we can only examine child mortality prior to 60 months. We shall term this age range "early childhood" (note that infancy is included). It is during these ages that breastfeeding and fertility affect child survival. Net of the influences of next pregnancy of mother, age and the other control variables, the hazard of dying for weaned children is about twice the hazard for the unweaned (see table 1; relative risk of 2.06). The lower bound of the 95 per cent confidence region puts the relative risk at a little greater than 1.4 while the upper bound places it just under 3.0. (The confidence intervals are asymmetrical because they are based on the logarithm of the relative risk; see Appendix B). Over 51 per cent of the sample had weaned by the time of the survey or prior to death. That per cent in combination with the relative risk produces an attributable risk of 35.22 (95 % CI, 16.63 - 49.67), i.e. breastfeeding practices account for up to 35 per cent of early childhood mortality (including infant mortality) in Egypt. The impact of weaning should be lower, or even non-existent, for older children since ordinarily they do not rely mainly on mother's milk for proper nutrition and immunization. For children weaned prior to twelve months, the relative risk is 4.29 (2.91 - 6.33), while for children weaned after twelve months, the relative risk drops to 1.95 (1.23 - 3.09). Note that although the relative risk is higher for children weaned prior to twelve months, the attributable risk is lower because only 12.54 per cent of children have weaned by that age. Early weaning before the end of infancy is responsible for up to 29.21 (17.84 - 39.01) per cent of child mortality. While comparing the births followed by contraception and those not followed by contraception, we note that the impact of weaning is greater for the unregulated but that the age pattern of effects (i.e. weaned at 12 months versus weaned at 12 months or older) is the same as for all births. Our explanation is that use of contraception probably selects on use of formal health care services, which itself should reduce the impact of weaning on survival.

Weaning can also influence child mortality by increasing the likelihood of the mother becoming pregnant again. The total relative risk consists of both direct and indirect components. The total effect of weaning on child death is 2.43 (see table 2) The direct component (discussed in the previous paragraph) constitutes 81.45 per cent of that total (in the log-scale; see Appendix B). In the unregulated fertility population, the direct component is somewhat smaller, 73.75 per cent. Breastfeeding is one of the primary inhibitors of pregnancy in the unregulated population, and thus a larger indirect effect is expected for these births. When weaning occurs relatively early (i.e. prior to twelve months), the direct share is 87.44 per cent for all children.

A.2 Effects of next pregnancy on child death [see figure 3]

We next consider the impact of next pregnancy of the mother on the child's survival. Other studies have attempted to capture the same effect by estimating effects of the length of the subsequent (or following) birth interval; results have varied from setting to setting. (For Egyptian results, see Callum and Cleland, 1988). As noted in section III, we take all next pregnancies into account, whether or not they eventuate in a live birth; the event of interest is conception (or the start of gestation). Once the mother becomes pregnant again, the hazard of the child dying increases by a factor of 1.88 (1.46 - 2.43) as compared to the hazard for children whose mother is not pregnant, net of the influences of weaning, age and the other control variables (see table 3). The pregnancy must have begun at least one month prior to either the death of the child or the survey if the child did not die. If the pregnancy started after the death of the child, it could not have produced a change in the risk of mortality. Next pregnancy is responsible for up to 26.72 (15.30 - 36.61) per cent of child mortality (attributable risk) . As in the case of weaning, the effect is larger when the mother becomes pregnant again during infancy, as opposed to when the child is twelve months or older. Note that a conception within twelve months of live birth represents rapidly-paced fertility. Such rapidly-paced fertility accounts for 22.20 (15.14 - 28.67) of child mortality (attributable risk). After the child achieves age twelve months, the impact of next pregnancy on the risk of dying largely disappears, a plausible result. One does not expect <u>all</u> subsequent fertility to be significantly disadvantageous for survival of an earlier child. The estimated effect is only slightly higher for the unregulated fertility population.

In addition to its direct impact, next pregnancy can also influence child mortality indirectly by inducing weaning. Over a quarter of the total effect of next pregnancy on child survival chances is transmitted through stoppage of breastfeeding (see table 4). When mothers become pregnant again less than twelve months after the birth of the child under consideration, the indirect share drops substantially, due primarily to an increase in the direct effect relative risk. After twelve months, only the indirect component shows significant impact.

B. Next pregnancy

B.1 Effects of weaning on next pregnancy [see figure 2]

Breastfeeding has well established health effects, but it also helps to regulate fertility by suppressing ovulation. For all children, the hazard that their mother will become pregnant again if they have been weaned is 3.02 (2.60 - 3.50) times the hazard if they have not weaned; this effect is net of child death, age and the other control variables (see table 5). Weaning is responsible for up to 41.08 (35.38 - 46.28) per cent of mothers becoming pregnant again (attributable risk).

It is with respect to this effect that we expect the greatest differences between the unregulated and regulated fertility population, because in most natural fertility populations breastfeeding is the primary inhibitor of becoming pregnant again (Bongaarts, 1983). Conforming to these expectations, the relative risk for the unregulated is 5.21 (4.04 - 6.71), while for the regulated it is 1.94 (1.59 - 2.37). Weaning accounts for up to 52.07 (43.45 - 59.38) per cent of next pregnancies for mothers who do not use contraception following the birth, while it is responsible for up to 31.97 (22.31 - 40.43) per cent of next pregnancies for mothers who do practice contraception (attributable risks). Relative risk estimates do not vary significantly by age of weaning.

Weaning can also boost the hazard of next pregnancy indirectly by increasing the chances of child death, which in turn spurs fertility through a variety of behavioral mechanisms, including deliberate efforts to replace the deceased child. In Egypt virtually all of the of impact of weaning on next pregnancy is direct, however (see table 6).

B.2 Effects of child death on next pregnancy [see figure 5]

We consider next the effect of child death on the risk of next pregnancy. While the other relationships in our system are primarily biologically-based, this effect is behavioral. Keep in mind that, as the micro-level system is defined for this analysis, child death does not cause weaning (rather, it censors it), and thus an indirect effect of death on next pregnancy through weaning is ruled out. The direct effect of child death on the risk of next pregnancy is usually termed "replacement": deliberate efforts, through changes in coital frequency or in contraceptive behavior, to increase the probability of another conception.

Net of weaning and the other control variables, the hazard of next pregnancy after child death is 3.22 (2.73 - 3.81) times the hazard of next pregnancy without a child death (see table 7). The share of next pregnancies attributable to child deaths is up to 18.16 (14.32 - 21.83) per cent. The relationship between child death and next pregnancy does not vary significantly by age or by fertility control practice.

C. Weaning

Effects of next pregnancy on weaning [see figure 4]

Finally, we turn to effects on the risk of weaning. In the previous two sections, we have summarized the evidence from the EFS that weaning boosts the hazards both of child death and of next pregnancy. Next pregnancy, in turn, can also increase the chances of weaning by suppressing the production of mother's milk. Children of pregnant mothers are 2.92 (2.72 - 3.14) times more likely to wean than children of non-pregnant mothers, net of the control variables (see table 8). Next pregnancy accounts for up to 24.96 (22.68 - 27.18) per cent of child weanings (attributable risk). For the unregulated population, the influence of next pregnancy is greater; the relative risk is 3.24 (2.96 - 3.55). In that population, next pregnancy is responsible for up to 28.27 (25.24 - 31.18) per cent of child weanings. In the regulated population, next pregnancy accounts for 16.97 (13.30 - 20.49) per cent of weanings. In the unregulated population but not among the contraceptive, the impact of next pregnancy on weaning changes significantly with age. Women who do not practice contraception tend to breastfeed longer; the onset of the next pregnancy curtails prolonged nursing.

V. SUMMARY AND CONCLUDING REMARKS

Reproductive behavior and child survival are related to each other through a complex set of mechanisms that operate at both the micro- and the macro-level. This analysis has examined the micro-level relationships between fertility and child survival, with explicit attention to the role of breastfeeding. Breastfeeding has direct effects on both fertility and child survival; it also mediates the association between the two. In populations where use of modern contraceptive techniques is at low levels - such as Egypt at the time of the 1980 EFS - breastfeeding is perhaps the single most important proximate determinant of fertility and child survival.

An important feature of the analysis contained in this report is that fertility (represented in this report by pregnancy), child survival, and breastfeeding are examined simultaneously as components of a micro-level system.

The analysis consists of regression models for the hazard, or risk, of three events occurring subsequent to a live birth: another pregnancy, weaning of the child, and death of the child. The important results, in brief, are as follows:

> Weaning prior to the end of infancy increases the risk of death for children under age 5 years. Such early weaning is responsible for up to 29 per cent of child deaths in Egypt. About 18 per cent of the effect of breastfeeding on child mortality is related to an increased risk of pregnancy. Children whose mothers become pregnant again are more likely to die if the pregnancy begins while the child is still in infancy. Such fast paced fertility accounts for up to 22 per cent of child deaths. About 26 per cent of the impact of pregnancy on child mortality is indirect by increasing the risk of weaning.
>
> After children wean, their mothers experience an increased risk of pregnancy. Cessation of breastfeeding practices is responsible for up to 41 per cent of pregnancies. Among women that do not use contraceptives, that figure rises to 52 per cent. Less than 2 per cent of the effect of breastfeeding on fertility acts indirectly through child mortality. Replacement behavior in response to deaths of children accounts for up to 18 percent of pregnancies.

When mothers become pregnant again, the chances that they will wean their children increase. Pregnancy is responsible for up to 24 per cent of the weanings in Egypt.

From a policy standpoint, several of the results merit further discussion. Weaning shows substantial impact on child survival. Given the relatively long average breastfeeding durations (17-18) months in Egypt, it does not seem reasonable to conclude from these results that Egyptian women should be encouraged to breastfeed their children longer. It should be noted that the relative risk of death once a child is weaned is much higher if weaning occurs during infancy; those women who do breastfeed for rather short durations, for whatever reason, probably should be encouraged to breastfeed longer. But the important conclusion to be derived from this result is that weaning can be traumatic for the child, and therefore great care must be taken with respect to diet, hygiene and child care in the period immediately following cessation of breastfeeding.

The overall impact of child mortality on fertility as measured by the attributable risk is lower than expected if high mortality is in fact a primary determinant of high fertility. Mortality does have an effect, but even in a high infant mortality country such as Egypt, infant deaths are still relatively rare events. For the most part, however, it is not actual mortality but perceptions of child survival chances that drive fertility.

Many analyses of this type distinguish between "biological" and "behavioral" relationships. We have avoided this distinction, because we find it difficult to fit the relationships under examination into this classification. A more useful distinction is between deliberate and non-deliberate behaviors (eg. pregnancies that are deliberate to replace a child who died and conceptions that are non-deliberate because of termination of the anovulatory effects of lactation). Motive can not usually be imputed directly from observed behavior since duration of breastfeeding is a function of biological, social and cultural variables, and these variables often overlap in their respective impacts.

For these reasons, we prefer to speak about distinct measurable behaviors rather than classifications that require assumptions about unmeasured attitudes and behaviors. Nevertheless, it is of some importance to recognize that in Egypt in the 1970s there is little evidence of deliberate efforts to act on levels of fertility; the measured levels of contraceptive practice are one of the indicators. There is also little evidence that decisions about how long to breastfeed were motivated mainly by child health or fertility considerations, although one can assume that concerns about child health were a factor. We do estimate a substantial effect of child death on the risk of a next pregnancy (net of weaning, i.e. controlling for breastfeeding), however. This suggests deliberate efforts to replace dead children - "replacement effects" - that are commonly termed "behavioral".

The powerful effects that emerge from this analysis are, for the most part, effects that are most reasonably assumed to be non-deliberate: weaning on the risk of child death; weaning on the risk of becoming pregnant again; child death on the risk of becoming pregnant again; pregnancy on weaning. At the same time, most of these relationships are susceptible to modification through deliberate public health policies and through individual behavioral changes. Note that some of these changes would impact the **attributable risk** but not the **relative risk**. For example, the relative risk of a pregnancy following a death may not change; but as child deaths become less common, this relationship accounts for fewer pregnancies. That is, it is essential to consider both the magnitude of effects and the relative size of the population at risk. Both are susceptible to macro-policy interventions and intentional individual efforts to change behavior.

TABLE 1

EGYPT 1975-80

THE DIRECT IMPACT OF WEANING ON CHILD MORTALITY (before age 60 months)

% per cent weaned (ceased breastfeeding prior to child death)
RR relative risk of child death (weaned / not weaned)
AR attributable risk of child death

	ALL (N=7375 children) EST. (95 % CI)	FERTILITY CONTROL: NO (N=4714 children) EST. (95 % CI)	FERTILITY CONTROL: YES (N=2661 children) EST. (95 % CI)
WEANED at any age			
%	51.19 (50.05 - 52.33)	44.63 (43.21 - 46.05)	62.80 (60.96 - 64.63)
RR	2.06 (1.43 - 2.98)	2.21 (1.34 - 3.65)	*
AR	35.22 (16.63 - 49.67)	35.10 (10.51 - 52.94)	*
WEANED before 12 months			
%	12.54 (11.79 - 13.30)	9.61 (8.77 - 10.45)	17.74 (16.29 - 19.19)
RR	4.29 (2.91 - 6.33)	5.13 (3.02 - 8.71)	3.35 (1.78 - 6.30)
AR	29.21 (17.84 - 39.01)	28.39 (13.52 - 40.71)	29.41 (7.91 - 45.89)
WEANED at 12 months or later			
%	57.25 (55.88 - 58.63)	57.39 (55.58 - 59.19)	57.07 (54.95 - 59.18)
RR	1.95 (1.23 - 3.09)	2.60 (1.44 - 4.68)	*
AR	35.17 (9.44 - 53.58)	47.81 (17.48 - 66.99)	*

based on Weibull proportional hazards model
controlling for: next pregnancy of mother,
parity, age of mother, preceding birth interval length,
sex, region, urban/rural residence, fertility control,
education of mother, education of father
based on data from the Egyptian Fertility Survey 1980
restrictions: children born within 60 months of survey to married women
last two children only
no multiple births
no marital disruption prior to child death
Muslim only
note: some children still breastfeeding at survey (not weaned)
some children breastfed until died (not weaned)
*-not statistically distinguishable
from 0.0 for per cent (%) and attributable risk (AR) and
from 1.0 for relative risk (RR)

TABLE 2
EGYPT 1975-80
DECOMPOSITION OF THE TOTAL IMPACT OF WEANING ON CHILD MORTALITY
(before age 60 months)

WEANED ceased breastfeeding prior to child death
PREGNANT mother became pregnant after weaning and prior to child death
RR relative risk of child death (weaned / not weaned)

			--------FERTILITY	CONTROL--------		
	ALL	ln(RR) %	NO	ln(RR) %	YES	ln(RR) %
WEANED RR at any age						
TOTAL	2.43	100.00 %	2.93	100.00 %	1.09	100.00 %
DIRECT	2.06	81.45 %	2.21	73.75 %	*	
INDIRECT (through pregnant)	1.18	18.55 %	1.33	26.25 %	1.09	100.00 %
WEANED RR before 12 months						
TOTAL	5.29	100.00 %	6.94	100.00 %	3.87	100.00 %
DIRECT	4.29	87.44 %	5.13	84.39 %	3.35	89.37 %
INDIRECT (through pregnant)	1.23	12.56 %	1.35	15.61 %	1.15	10.63 %
WEANED RR at 12 months or later						
TOTAL	1.95	100.00 %	2.60	100.00 %	*	
DIRECT	1.95	100.00 %	2.60	100.00 %	*	
INDIRECT (through pregnant)	*		*		*	

based on Weibull proportional hazards and log-logistic models
controlling for: next pregnancy of mother, weaning,
parity, age of mother, preceding birth interval length,
sex, region, urban/rural residence, fertility control,
education of mother, education of father
indirect effects evaluated at mean age of pregnancy
based on data from the Egyptian Fertility Survey 1980
restrictions: children born within 60 months of survey to married women
last two children only
no multiple births
no marital disruption prior to child death
Muslim only
*-not statistically distinguishable from 1.0

TABLE 3
EGYPT 1975-80
THE DIRECT IMPACT OF NEXT PREGNANCY ON CHILD MORTALITY (before age 60 months)

% per cent pregnant (mother became pregnant prior to child death)
RR relative risk of child death (pregnant / not pregnant)
AR attributable risk of child death

	ALL (N=7375 children)	FERTILITY CONTROL: NO (N=4714 children)	FERTILITY CONTROL: YES (N=2661 children)
	EST. (95 % CI)	EST. (95 % CI)	EST. (95 % CI)
PREGNANT at any age			
%	41.30 (40.18 - 42.43)	38.27 (36.88 - 39.66)	46.67 (44.78 - 48.57)
RR	1.88 (1.46 - 2.43)	2.08 (1.52 - 2.85)	1.74 (1.11 - 2.74)
AR	26.72 (15.30 - 36.61)	29.29 (15.52 - 40.82)	25.74 (2.37 - 43.52)
PREGNANT before 12 months			
%	13.45 (12.67 - 14.23)	13.47 (12.50 - 14.45)	13.42 (12.12 - 14.71)
RR	3.12 (2.40 - 4.06)	3.34 (2.40 - 4.66)	2.67 (1.70 - 4.19)
AR	22.20 (15.14 - 28.67)	23.99 (14.70 - 32.27)	18.31 (6.71 - 28.46)
PREGNANT at 12 months or later			
%	41.26 (39.89 - 42.63)	40.63 (38.84 - 42.43)	42.12 (40.01 - 44.23)
RR	*	*	*
AR	*	*	*

based on Weibull proportional hazards model
controlling for: weaning,
parity, age of mother, preceding birth interval length,
sex, region, urban/rural residence, fertility control,
education of mother, education of father
based on data from the Egyptian Fertility Survey 1980
restrictions: children born within 60 months of survey to married women
last two children only
no multiple births
no marital disruption prior to child death
Muslim only
note: some mothers do not become pregnant by survey
*-not statistically distinguishable
from 0.0 for per cent (%) and attributable risk (AR) and
from 1.0 for relative risk (RR)

TABLE 4
EGYPT 1975-80
DECOMPOSITION OF THE TOTAL IMPACT OF NEXT PREGNANCY ON CHILD MORTALITY
(before age 60 months)

PREGNANT mother becamse pregnant prior to child death
WEANED ceased breastfeeding after mother became pregnant
and prior to child death
RR relative risk of child death (pregnant / not pregnant)

			--------FERTILITY CONTROL--------			
	ALL	ln(RR) %	NO	ln(RR) %	YES	ln(RR) %
<u>PREGNANT RR at any age</u>						
TOTAL	2.34	100.00 %	2.61	100.00 %	1.74	100.00 %
DIRECT	1.88	74.27 %	2.08	76.36 %	1.74	100.00 %
INDIRECT (through weaned)	1.25	25.73 %	1.25	23.64 %	*	
<u>PREGNANT RR before 12 months</u>						
TOTAL	3.71	100.00 %	3.80	100.00 %	3.10	100.00 %
DIRECT	3.12	86.88 %	3.34	90.33 %	2.67	86.93 %
INDIRECT (through weaned)	1.19	13.12 %	1.14	9.67 %	1.16	13.07 %
<u>PREGNANT RR at 12 months or later</u>						
TOTAL	1.31	100.00 %	1.55	100.00 %	*	
DIRECT	*		*		*	
INDIRECT (through weaned)	1.31	100.00 %	1.55	100.00 %	*	

based on Weibull proportional hazards and log-logistic models
controlling for: weaning, next pregnancy of mother,
parity, age of mother, preceding birth interval length,
sex, region, urban/rural residence, fertility control,
education of mother, education of father
indirect effects evaluated at mean age of weaning
based on data from the Egyptian Fertility Survey 1980
restrictions: children born within 60 months of survey to married women
last two children only
no multiple births
no marital disruption prior to child death
Muslim only
*-not statistically distinguishable from 1.0

TABLE 5
EGYPT 1975-80
THE DIRECT IMPACT OF WEANING ON NEXT PREGNANCY OF MOTHER (before age 60 months)

% per cent weaned (ceased breastfeeding prior to next pregnancy)
RR relative risk of pregnancy of mother (weaned / not weaned)
AR attributable risk of pregnancy of mother

	ALL (N=7375 children)	FERTILITY CONTROL: NO (N=4714 children)	FERTILITY CONTROL: YES (N=2661 children)
	EST. (95 % CI)	EST. (95 % CI)	EST. (95 % CI)
<u>WEANED at any age</u>			
%	34.58 (33.49 - 35.66)	25.82 (24.57 - 27.07)	50.09 (48.19 - 51.99)
RR	3.02 (2.60 - 3.50)	5.21 (4.04 - 6.71)	1.94 (1.59 - 2.37)
AR	41.08 (35.38 - 46.28)	52.07 (43.45 - 59.38)	31.97 (22.31 - 40.43)
<u>WEANED before 12 months</u>			
%	8.98 (8.32 - 9.63)	5.71 (5.04 - 6.37)	14.77 (13.42 - 16.12)
RR	2.91 (2.43 - 3.47)	4.69 (3.43 - 6.42)	2.06 (1.63 - 2.60)
AR	14.60 (11.04 - 18.02)	17.39 (11.20 - 23.14)	13.51 (7.89 - 18.79)
<u>WEANED at 12 months or later</u>			
%	42.19 (40.74 - 43.64)	37.66 (35.77 - 39.56)	48.01 (45.80 - 50.22)
RR	3.07 (2.48 - 3.79)	6.06 (4.04 - 9.10)	1.84 (1.41 - 2.41)
AR	46.62 (38.15 - 53.93)	65.60 (52.60 - 75.04)	28.74 (15.52 - 39.90)

based on log-logistic model
controlling for: child death,
parity, age of mother, preceding birth interval length,
sex, region, urban/rural residence, fertility control,
education of mother, education of father
based on data from the Egyptian Fertility Survey 1980
restrictions: children born within 60 months of survey to married women
last two children only
no multiple births
no marital disruption prior to child death
Muslim only
note: some children still breastfeeding at survey (not weaned)
some children breastfed until died (not weaned)
*-not statistically distinguishable
from 0.0 for per cent (%) and attributable risk (AR) and
from 1.0 for relative risk (RR)

TABLE 6
EGYPT 1975-80
DECOMPOSITION OF THE TOTAL IMPACT OF WEANING ON NEXT PREGNANCY OF MOTHER
(before age 60 months)

WEANED ceased breastfeeding prior to next pregnancy of mother
DEATH child death prior to next pregnancy of mother and after weaning
RR relative risk of pregnancy of mother (weaned / not weaned)

			--------FERTILITY CONTROL--------			
	ALL	ln(RR) %	NO	ln(RR) %	YES	ln(RR) %
WEANED RR at any age						
TOTAL	3.07	100.00 %	5.28	100.00 %	1.94	100.00 %
DIRECT	3.02	98.51 %	5.21	99.16 %	1.94	100.00 %
INDIRECT (through child death)	1.02	1.49 %	1.01	0.84 %	*	
WEANED RR before 12 months						
TOTAL	3.00	100.00 %	4.81	100.00 %	2.18	100.00 %
DIRECT	2.91	97.12 %	4.69	98.38 %	2.06	92.70 %
INDIRECT (through child death)	1.03	2.88 %	1.03	1.62 %	1.06	7.30 %
WEANED RR at 12 months or later						
TOTAL	3.07	100.00 %	6.06	100.00 %	1.84	100.00 %
DIRECT	3.07	100.00 %	6.06	100.00 %	1.84	100.00 %
INDIRECT (through child death)	*		*		*	

based on Weibull proportional hazards and log-logistic models
controlling for: child death, weaning,
parity, age of mother, preceding birth interval length,
sex, region, urban/rural residence, fertility control,
education of mother, education of father
indirect effects evaluated at mean age of children
based on data from the Egyptian Fertility Survey 1980
restrictions: children born within 60 months of survey to married women
last two children only
no multiple births
no marital disruption prior to child death
Muslim only
*-not statistically distinguishable from 1.0

TABLE 7
EGYPT 1975-80
THE DIRECT IMPACT OF CHILD DEATH ON NEXT PREGNANCY OF MOTHER
(before age 60 months)

% per cent dead (child death prior to pregnancy of mother)
RR relative risk of pregnancy of mother (child death / no child death)
AR attributable risk of pregnancy of mother

	ALL (N=7375 children) EST (95 % CI)	FERTILITY CONTROL: NO (N=4714 children) EST. (95 % CI)	FERTILITY CONTROL: YES (N=2661 children) EST. (95 % CI)
CHILD DEATH at any age			
%	9.98 (9.30 - 10.66)	10.73 (9.85 - 11.62)	8.64 (7.57 - 9.71)
RR	3.22 (2.73 - 3.81)	3.22 (2.62 - 3.95)	3.16 (2.34 - 4.26)
AR	18.16 (14.32 - 21.83)	19.22 (14.28 - 23.88)	15.73 (9.49 - 21.54)
CHILD DEATH before 12 months			
%	8.88 (8.23 - 9.53)	9.50 (8.67 - 10.34)	7.78 (6.76 - 8.80)
RR	3.25 (2.74 - 3.85)	3.19 (2.59 - 3.92)	3.23 (2.39 - 4.36)
AR	16.64 (13.03 - 20.11)	17.21 (12.62 - 21.56)	14.76 (8.82 - 20.31)
CHILD DEATH at 12 months or later			
%	1.81 (1.42 - 2.20)	2.30 (1.72 - 2.89)	1.17 (0.70 - 1.65)
RR	*	*	*
AR	*	*	*

based on log-logistic model
controlling for: weaning,
parity, age of mother, preceding birth interval length,
sex, region, urban/rural residence, fertility control,
education of mother, education of father
based on data from the Egyptian Fertility Survey 1980
restrictions: children born within 60 months of survey to married women
last two children only
no multiple births
no marital disruption prior to child death
Muslim only
note: some children still alive at survey
*-not statistically distinguishable
from 0.0 for per cent (%) and attributable risk (AR) and
from 1.0 for relative risk (RR)

TABLE 8
EGYPT 1975-80
THE DIRECT IMPACT OF NEXT PREGNANCY ON WEANING (before age 60 months)

% per cent pregnant (mother became pregnant prior to weaning)
RR relative risk of weaning (pregnant / not pregnant)
AR attributable risk of weaning

	ALL (N-7375 children) EST. (95 % CI)	FERTILITY CONTROL: NO (N=4714 children) EST. (95 % CI)	FERTILITY CONTROL: YES (N-2661 children) EST. (95 % CI)
PREGNANT at any age			
%	17.33 (16.46 - 18.19)	17.59 (16.50 - 18.67)	16.87 (15.45 - 18.30)
RR	2.92 (2.72 - 3.14)	3.24 (2.96 - 3.55)	2.21 (1.94 - 2.52)
AR	24.96 (22.68 - 27.18)	28.27 (25.24 - 31.18)	16.97 (13.30 - 20.49)
PREGNANT before 12 months			
%	9.36 (8.69 - 10.02)	9.86 (9.01 - 10.71)	8.45 (7.40 - 9.51)
RR	2.92 (2.71 - 3.15)	2.90 (2.63 - 3.20)	2.19 (1.88 - 2.54)
AR	15.23 (13.49 - 16.93)	15.77 (13.44 - 18.04)	9.12 (6.59 - 11.59)
PREGNANT at 12 months or later			
%	14.87 (13.77 - 15.98)	15.29 (13.85 - 16.74)	14.24 (12.51 - 15.97)
RR	3.20 (2.87 - 3.58)	3.91 (3.43 - 4.47)	2.27 (1.82 - 2.82)
AR	24.68 (21.31 - 27.90)	30.82 (26.37 - 35.01)	15.29 (9.82 - 20.43)

based on Weibull proportional hazards model
controlling for: parity, age of mother, preceding birth interval length, sex, region, urban/rural residence, fertility control, education of mother, education of father
based on data from the Egyptian Fertility Survey 1980
restrictions: children born within 60 months of survey to married women
last two children only
no multiple births
no marital disruption prior to child death
Muslim only
note: some mothers do not become pregnant by survey
*-not statistically distinguishable
from 0.0 for per cent (%) and attributable risk (AR) and
from 1.0 for relative risk (RR)

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Appendix A

PROBABILITY DISTRIBUTIONS AND LIKELIHOOD DEFINITION

A combination of three parametric failure models for each of the three outcomes under consideration: child death, weaning and next pregnancy of mother, is the basis for estimation via maximum likelihood.

For child death and weaning, the failure distribution is Weibull. The Weibull distribution is appropriate when the hazard increases or decreases monotonically with duration. It is suitable for the examination of child mortality because the hazard of death declines with age. The Weibull is also applicable to the analysis of breastfeeding since the hazard of weaning increases monotonically with age in most populations. The Weibull is a proportional hazards model.

For next pregnancy of the mother, the Weibull is not utilizable because the hazard of conception is not monotonic. The log-logistic distribution effectively captures such a curvilinear pattern. The hazard of conception first increases with age, levels out and then declines as the time interval lengthens which reflects the selection by sub-fecundity of those mothers who have not become pregnant again.

SURVIVAL DISTRIBUTIONS

```
T            : time (T > 0)
ALPHA        : level
BETA         : shape (age)
GAMMA, DELTA : effects of the other events
XB           : combination of covariates
```

<u>Weibull</u>

```
BETA = 1.0 indicates constant hazard
BETA < 1.0 indicates monotone decreasing hazard
BETA > 1.0 indicates monotone increasing hazard

survival function:
      S(t) := exp( - exp( ALPHA + BETA*ln(T) )
hazard rate function:
      h(t) := BETA*exp( ALPHA + (BETA - 1.0)*ln(T))
```

<u>Log-logistic</u>

```
BETA = 1.0 indicates monotone decreasing hazard
      from exp(ALPHA/BETA)
BETA < 1.0 indicates monotone decreasing hazard
      from infinity
BETA > 1.0 indicates increasing hazard to maximum
      at ( (BETA - 1.0)**(1.0 / BETA) ) / exp(ALPHA/BETA)
      and decreasing thereafter

survival function:
      S(t) := 1.0 / ( 1.0 + exp( ALPHA + BETA*ln(T) )
hazard rate function:
      h(t) := ( BETA*exp( ALPHA + (BETA - 1.0)*ln(T) )
             / ( 1.0 + exp( ALPHA + BETA*ln(T) )
```

<u>With covariates</u>

$S_0(t)$: baseline survival function (GAMMA, DELTA, XB = 0)
$h_0(t)$: baseline hazard function
$S(t) := \exp(\ln(S_0(t))*\exp(GAMMA + DELTA + XB))$
$h(t) := h_0(t)*\exp(GAMMA + DELTA + XB)$

LIKELIHOOD DEFINITION

lik : likelihood for a particular observation

T : time of censoring
T_1 : time of event 1
T_2 : time of event 2
T_3 : time of event 3
T_1, T_2, T_3 represent the ordered ages at death, weaning and conception for a particular observation

$h_1()$: hazard for event 1
$S_1()$: survival function for event 1
$h_2()$: hazard for event 2
$S_2()$: survival function for event 2
$S_{2|1}()$: modified survival function for event 2 after the occurrence event 1
$h_3()$: hazard for event 3
$S_3()$: survival function for event 3
$S_{3|1}()$: modified survival function for event 3 after the occurrence of event 1
$S_{3|2}()$: modified survival function for event 3 after the occurrence of events 2 and 1

for T1 < T2 < T3 :

$$lik = S_1(T_1)*h_1(T_1)*S_2(T_1)*S_3(T_1)* (S_{2|1}(T_2)/S_{2|1}(T_1))*h_2(T_2)*(S_{3|1}(T_2)/S_{3|1}(T_1))* (S_{3|2}(T_3)/S_{3|2}(T_2))*h_3(T_3)$$

for T1 < T2 < T3 = T :

$$lik = S_1(T_1)*h_1(T_1)*S_2(T_1)*S_3(T_1)* (S_{2|1}(T_2)/S_{2|1}(T_1))*h_2(T_2)*(S_{3|1}(T_2)/S_{3|1}(T_1))* (S_{3|2}(T)/S_{3|2}(T_2))$$

for T1 < T2 = T3 = T :

$$lik = S_1(T_1)*h_1(T_1)*S_2(T_1)*S_3(T_1)* (S_{2|1}(T)/S_{2|1}(T_1))*(S_{3|1}(T)/S_{3|1}(T_1))$$

for T1 = T2 = T3 = T :

$$lik = S_1(T)*S_2(T)*S_3(T)$$

Appendix B

PROPORTIONS, RELATIVE RISKS AND ATTRIBUTABLE RISKS: ESTIMATES, STANDARD ERRORS AND CONFIDENCE INTERVALS

Proportions measure the prevalence of particular characteristics in a population. The error variance for an estimated proportion is P*(1-P)/N where P is the estimated proportion and N is the sample size. The standard error is, of course, the square root of the error variance. The sampling distribution for estimated proportions is asymptotically normal. Tables in this paper report per cents (100*P).

The relative risk is the ratio of the hazard of an event given the presence of a particular characteristic to the hazard of the same event given the absence of the same characteristic. In this analysis, we examine hazards of child death, weaning and next pregnancy of mother. Because the sampling distribution of an estimated relative risk is not normal, the error variance of the estimate is not generally useful. Maximum likelihood produces an estimate of the logarithm of the relative risk which is distributed asymptotically normal, and the Cramer-Rao theorem provides the error variance. In addition to reporting the relative risk, net of the other variables in the system, we also present a decomposition that partitions the relative risk into two components. The first piece, which we call the direct effect, is the standard relative risk of an outcome, net of all other factors in the models. For the indirect effect, we use the other major factor in our system. (eg. For the impact of weaning on child death, we show the indirect effect of weaning through next pregnancy of mother.) The indirect relative risk is: exp(B*(S - Sa)) where B is the log of the relative risk of an outcome for the intervening factor; S is the survival function for that intervening factor when it is treated as an outcome and the direct factor has no influence it; Sa is that same survival function but when the direct factor does have an impact. The indirect component is a non-linear combination, so we evaluate it at the mean duration of the intervening variable. The total is the product of the direct and indirect components. By taking logarithms, the components become additive, so in the log-scale we compute per cents of the total for the direct and direct pieces.

The attributable risk (AR) is: P*(R-1) / (1 + P*(R-1)) where P is the proportion of population with a particular factor and R is the relative risk. It represents the maximum proportion of a particular outcome that is attributable to that factor. For example, the attributable risk for child death represents how much of child mortality for which a particular factor is responsible. An important assumption is that the relative risk and the proportion are independent; the prevalence of a factor does not change its effect. Most studies report AR as a per cent (100*AR). Tables in this paper follow that convention. As in the case of the relative risk, the sampling distribution of the attributable risk is not normal. Walter (1975) shows that the logarithm of one minus the attributable risk (log(1 - AR)) has an asymptotic normal distribution. The error variance is:

```
( sqr(R-1)*var(P) + sqr(P)*sqr(R)*var(log(R)) ) /
      sqr(1 + P*(R-1))
```

After estimating parameters and establishing that coefficients are at least twice (actually 1.96) their standard errors which indicates significance at the typical level of .05, most researchers usually ignore error variances. In our view, a more useful approach is to produce ranges in addition to point estimates. Confidence intervals provide upper and lower bounds for estimates. In the examination of child mortality, breastfeeding and fertility, the ability to produce high and low estimates of the impact of factors is particularly important because of the policy implications. While standard errors provide essentially the same information as confidence intervals, they are less tractable in practice because researchers usually disregard error variances after establishing statistical significance. Confidence bounds display that variability in a form that is readily interpretable. A 95 per cent confidence interval corresponds to a significance level of .05; the interpretation is that 95 times out of 100, the population parameter will fall within the range.

Another reason for reporting confidence limits in lieu of standard errors is that tests which are based on the normal distribution for the relative risk and the attributable risk are not optimal. The logarithms of the two statistics work better. Significance tests are performed on log-transforms of the estimates, so reporting coefficients and standard errors might lead to performing an inappropriate test. Log-transforms of estimates can be reported, but those coefficients are not readily interpretable. Confidence bounds are computed in the log-scale and converted into interpretable numbers. Confidence intervals convey the variability in estimates while providing numbers that have straightforward interpretations.

Appendix C

VARIABLE DEFINITIONS

Age at death is measured in months and is either the age at death or censoring. Age at weaning is measured in months and is either the age at weaning, death or censoring. Children who die while breastfeeding are not considered weaned. Children who never breastfeed are not considered weaned since they were never at risk of weaning. Age at next pregnancy is measured in months and is either the age of a child at the onset of next pregnancy or censoring. If the next pregnancy produced a live birth, the onset of that pregnancy is nine months prior, the standard length of gestation. If the next pregnancy produced a non-live outcome, the onset of that pregnancy is the reported months of gestation prior. If the next pregnancy is the current pregnancy of mother, the onset of that pregnancy is the number of months pregnant prior. Ages for children who die before their mothers become pregnant are how old they would have been if they had lived. Censoring can occur at any age.

To mitigate spurious influences in the interrelations in the above variables, the models contain a set of controls. Some of these controls are birth-specific, while the remainder are socio-economic and pertain to the household or community.

Birth-specific. Fertility regulation is measured as a dichotomy: no use of contraceptives after the birth and before the next birth versus any use. Preceding birth interval is divided into four categories: less than 18 months, 18 to 35 months, 36 months or longer, and first birth which has an undefined interval. Age of mother has three categories: less than 20 years, 20 - 34, and 35 or older. Parity is treated continuously and ranges from 1 to 15. Sex has, of course, two categories: male and female.

Socio-economic. Egypt is divided into two regions: Lower and Upper (referring to the Nile River). Size of place of residence has three categories: large urban (Cairo and Alexandria), small urban, and rural. Maternal and paternal education have the same breakdown into three groups: illiterate, literate with no formal schooling and literate with formal schooling.

Appendix D

Estimated models

In the following pages, coefficients, asymptotic standard errors, and ratios of coefficients to standard errors are presented for all of the models that are the basis of Tables 1 - 8.

-2*LOG-LIKELIHOOD = 64781.22660 DF = 7318

PARAMETER	ESTIMATE	STANDARD ERROR	ESTIMATE/SE
WEAN			
1 constant	-5.77736	0.09875	-58.50401
2 age	2.08645	0.02489	83.84167
3 next pregnancy	1.06149	0.03664	28.96918
4 birth control	0.13158	0.03609	3.64555
5 parity one	0.20444	0.06062	3.37225
6 birth int < 18	0.20446	0.05598	3.65232
7 birth int 18-35	0.05655	0.04519	1.25143
8 mom age < 20 yr	-0.15241	0.05056	-3.01474
9 mom age > 34 yr	0.07214	0.07272	0.99203
10 parity	-0.04203	0.01010	-4.16257
11 female	0.12194	0.03277	3.72085
12 lower nile	-0.32278	0.03770	-8.56131
13 small urban	0.12100	0.05201	2.32646
14 rural	-0.21338	0.04831	-4.41641
15 mom illiterate	-0.45664	0.05633	-8.10609
16 mom literate	-0.27541	0.07084	-3.88806
17 dad illiterate	-0.26136	0.04723	-5.53340
18 dad literate	-0.11483	0.04825	-2.38011
DEAD			
19 constant	-7.92094	0.32519	-24.35815
20 age	0.77965	0.05479	14.23011
21 weaned	0.72379	0.18821	3.84561
22 next pregnancy	0.63287	0.12959	4.88350
23 wean age equal	2.99540	0.16072	18.63737
24 birth control	-0.04542	0.09375	-0.48454
25 parity one	0.80304	0.18426	4.35811
26 birth int < 18	1.64228	0.14873	11.04167
27 birth int 18-35	0.76456	0.14062	5.43699
28 mom age < 20 yr	0.31135	0.12665	2.45841
29 mom age > 34 yr	-0.12535	0.16192	-0.77415
30 parity	0.05451	0.02055	2.65317
31 female	0.23220	0.08500	2.73190
32 lower nile	0.09922	0.09401	1.05542
33 small urban	-0.22234	0.15671	-1.41880
34 rural	-0.39335	0.13523	-2.90873
35 mom illiterate	0.22915	0.20124	1.13870
36 mom literate	0.29397	0.23516	1.25006
37 dad illiterate	0.12394	0.13377	0.92658
38 dad literate	-0.08124	0.14734	-0.55134
NEXT PREGNANCY			
39 constant	-6.30765	0.14375	-43.87961
40 age	1.82843	0.02993	61.08365
41 weaned	1.10407	0.07590	14.54607
42 child death	1.17045	0.08555	13.68080
43 birth control	-0.50539	0.05702	-8.86285
44 parity one	1.16782	0.09463	12.34099
45 birth int < 18	0.79657	0.08759	9.09430
46 birth int 18-35	0.60527	0.07030	8.61015
47 mom age < 20 yr	-0.17206	0.08301	-2.07280
48 mom age > 34 yr	-0.79622	0.10133	-7.85804
49 parity	-0.09180	0.01429	-6.42477
50 female	0.10084	0.05163	1.95322
51 lower nile	-0.09616	0.05846	-1.64475
52 small urban	0.09461	0.08924	1.06017
53 rural	0.10208	0.07983	1.27865
54 mom illiterate	0.10785	0.09519	1.13300
55 mom literate	0.19503	0.11578	1.68448
56 dad illiterate	-0.02578	0.07642	-0.33728
57 dad literate	0.01426	0.08047	0.17720

CHLILDREN IN REGULATED FERTILITY

-2*LOG-LIKELIHOOD =		27005.26560 DF =	2607
PARAMETER	ESTIMATE	STANDARD ERROR	ESTIMATE/SE
WEAN			
1 constant	-5.16281	0.13400	-38.52797
2 age	1.94831	0.03593	54.22412
3 next pregnancy	0.79359	0.06729	11.79401
4 parity one	0.23283	0.09858	2.36172
5 birth int < 18	0.17537	0.09080	1.93141
6 birth int 18-35	0.02184	0.06974	0.31322
7 mom age < 20 yr	-0.05083	0.09510	-0.53446
8 mom age > 34 yr	0.15402	0.11500	1.33925
9 parity	-0.05426	0.01632	-3.32544
10 female	0.16942	0.05428	3.12111
11 lower nile	-0.23081	0.06580	-3.50775
12 small urban	0.03867	0.07773	0.49745
13 rural	-0.25986	0.07714	-3.36849
14 mom illiterate	-0.41519	0.08124	-5.11079
15 mom literate	-0.26271	0.10042	-2.61599
16 dad illiterate	-0.26590	0.07826	-3.39766
17 dad literate	-0.08977	0.07764	-1.15623
DEAD			
18 constant	-8.03638	0.52100	-15.42488
19 age	0.76552	0.10293	7.43749
20 weaned	0.59670	0.30895	1.93139
21 next pregnancy	0.55544	0.23098	2.40473
22 wean age equal	2.63319	0.23976	10.98252
23 parity one	0.77060	0.32258	2.38891
24 birth int < 18	1.44143	0.25627	5.62476
25 birth int 18-35	0.48699	0.24719	1.97011
26 mom age < 20 yr	0.40243	0.23389	1.72060
27 mom age > 34 yr	-0.13588	0.27582	-0.49264
28 parity	0.11032	0.03627	3.04178
29 female	0.50075	0.15335	3.26548
30 lower nile	0.26951	0.17328	1.55540
31 small urban	-0.28191	0.24917	-1.13142
32 rural	-0.38931	0.22649	-1.71891
33 mom illiterate	0.24093	0.30143	0.79929
34 mom literate	0.37938	0.33501	1.13246
35 dad illiterate	0.24730	0.22934	1.07830
36 dad literate	0.00989	0.24413	0.04052
NEXT PREGNANCY			
37 constant	-7.26452	0.21366	-34.00101
38 age	1.87621	0.04999	37.53548
39 weaned	0.66171	0.10212	6.47965
40 child death	1.15066	0.15239	7.55055
41 parity one	1.29194	0.14993	8.61692
42 birth int < 18	0.59289	0.13696	4.32881
43 birth int 18-35	0.64666	0.10889	5.93889
44 mom age < 20	-0.03524	0.14045	-0.25091
45 mom age > 34	-0.51379	0.16089	-3.19331
46 parity	-0.14237	0.02341	-6.08268
47 female	0.23600	0.08093	2.91609
48 lower nile	0.18572	0.09800	1.89501
49 small urban	-0.06510	0.12224	-0.53260
50 rural	0.39490	0.11449	3.44916
51 mom illiterate	0.31615	0.12565	2.51619
52 mom literate	0.16286	0.15398	1.05773
53 dad illiterate	0.26774	0.11246	2.38077
54 dad literate	0.18974	0.11505	1.64918

CHLILDREN IN UNREGULATED FERTILITY

-2*LOG-LIKELIHOOD = 37446.21870 DF = 4660

PARAMETER	ESTIMATE	STANDARD ERROR	ESTIMATE/SE
WEAN			
1 constant	-6.14996	0.14564	-42.22591
2 age	2.19092	0.03608	60.72075
3 next pregnancy	1.17593	0.04674	25.15649
4 parity one	0.16364	0.07891	2.07368
5 birth int < 18	0.21158	0.07437	2.84497
6 birth int 18-35	0.09308	0.06310	1.47496
7 mom age < 20 yr	-0.20997	0.06102	-3.44114
8 mom age > 34 yr	0.02201	0.09572	0.22997
9 parity	-0.03554	0.01331	-2.66956
10 female	0.08002	0.04284	1.86797
11 lower nile	-0.39102	0.04713	-8.29672
12 small urban	0.18224	0.08294	2.19730
13 rural	-0.16746	0.07159	-2.33911
14 mom illiterate	-0.47239	0.08742	-5.40372
15 mom literate	-0.27384	0.10683	-2.56325
16 dad illiterate	-0.23737	0.06152	-3.85838
17 dad literate	-0.14083	0.06352	-2.21711
DEAD			
18 constant	-8.03881	0.42381	-18.96808
19 age	0.84979	0.06505	13.06400
20 weaned	0.79388	0.25572	3.10445
21 next pregnancy	0.73357	0.16081	4.56166
22 wean age equal	3.28660	0.22934	14.33053
23 parity one	0.84925	0.22903	3.70805
24 birth int < 18	1.76468	0.18502	9.53802
25 birth int 18-35	0.90902	0.17311	5.25117
26 mom age < 20 yr	0.24000	0.15500	1.54842
27 mom age > 34 yr	-0.11134	0.20403	-0.54572
28 parity	0.02507	0.02572	0.97475
29 female	0.08590	0.10388	0.82690
30 lower nile	0.02061	0.11430	0.18035
31 small urban	-0.14467	0.21242	-0.68105
32 rural	-0.37597	0.17672	-2.12753
33 mom illiterate	0.04253	0.28715	0.14812
34 mom literate	0.10267	0.34451	0.29802
35 dad illiterate	0.06827	0.16939	0.40301
36 dad literate	-0.13053	0.19050	-0.68523
NEXT PREGNANCY			
37 constant	-5.42813	0.20886	-25.98915
38 age	1.84445	0.03852	47.88864
39 weaned	1.65029	0.12947	12.74600
40 child death	1.16849	0.10475	11.15523
41 parity one	1.07288	0.12635	8.49128
42 birth int < 18	0.91234	0.11742	7.76984
43 birth int 18-35	0.52352	0.09524	5.49705
44 mom age < 20 yr	-0.31098	0.10629	-2.92583
45 mom age > 34 yr	-0.97314	0.13599	-7.15583
46 parity	-0.07472	0.01870	-3.99636
47 female	0.01366	0.06896	0.19808
48 lower nile	-0.21735	0.07553	-2.87763
49 small urban	0.14147	0.13802	1.02494
50 rural	-0.19992	0.11613	-1.72149
51 mom illiterate	-0.43476	0.15603	-2.78631
52 mom literate	-0.05406	0.18759	-0.28816
53 dad illiterate	-0.26091	0.10911	-2.39122
54 dad literate	-0.15034	0.11669	-1.28838

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